SHIFT CONTROL APPARATUS AND METHOD FOR HYBRID TRANSMISSION APPLICABLE TO HYBRID VEHICLE

BACKGROUND OF THE INVENTION:

5   **Field of the invention**

[0001]   The present invention relates to shift control apparatus and method for a hybrid transmission suitable for use in a hybrid vehicle in which a main power source such as an engine and

10   motor/generators are mounted.   The present invention particularly relates to the shift control apparatus and method which are capable of having a differential equipment (unit) interposed between the main power source and the motor/generators carry out a

15   continuously variable shift operation.

              Description of the related art

[0002]   Such a kind of hybrid transmission as described above, for example, includes a differential unit having two degrees of freedom and which is

20   constituted by a planetary gear group or so forth. An input from the engine which is the main power source, an output to a drive system, and a plurality of motor/generators are mutually coupled to respective revolutional members of the differential unit so that

25   powers from the motor/generators permit the continuously variable shift operation. In the above-described hybrid transmission, the motor/generators are driven by means of an electric power of a battery. However, when this driving is carried out, it is

30   necessary for the motor/generators to be driven at a power equal to or lower than a power rating of the battery in the same case as the drive for a normally available electrical equipment.

[0003]   A Japanese Patent Application First Publication No. Heisei 9-191506 published on July 22, 1997 exemplifies a previously proposed technique controlling the drive torque to the motor/generators (function as motors) in accordance with a state of the battery. In the previously proposed technique disclosed in the above-identified Japanese Patent Application First Publication, an electric vehicle in which a motor is driven along with a charge-and-discharge of the battery which serves as a power source is prerequisite. When a state variable of the battery is varied by a reference value or more such as reductions in a battery voltage or a battery residual capacity equal to or lower than a reference value, a response speed of a torque control for a drive torque command to the motor is slowed so that an earlier deterioration of the battery is prevented.

SUMMARY OF THE INVENTION:

[0004]   However, if the above-described technique is used to the hybrid transmission of the above-described type which is the prerequisite, viz., the hybrid transmission in which the input from the engine (main power source), the output to the drive system, and the motor/generators are mutually coupled via the differential unit having the two degrees of freedom and the powers from the motor/generators can modify limitlessly a ratio between input and output revolutions of the transmission (shift ratio) by means of the powers from the motor/generators, the battery residual capacity or battery voltage is lowered to a value equal to or lower than the reference value or a battery temperature is raised by a value equal to or higher than a reference value. At

this time, if a control form is adopted in which the response speed is slowed to the command of the motor/generator, the following problems occur.

[0005]   In details, in such a kind of the hybrid transmission as described above, the drive torque to the output of the drive system and a shift speed (input revolution acceleration) are mutually related to each other. As described in the previously proposed technique, if the drive torques of the motor/generators in accordance with only the state of the battery without the shift speed (input revolution acceleration) taken into consideration are limited, there is a possibility that the shift speed (input revolution acceleration) is in an opposite direction to a direction that the driver has expected. If the shift speed (input revolution acceleration) is in the opposite direction that the driver has desired, an input revolution speed variation (engine revolution speed variation) which is opposite to that the driver has expected from a driving operation occurs. There is a possibility of the shift such that a sense of incompatibility is given to the driver. Then, there is an anxiety that a reduction of a shift quality is introduced.

[0006]   It is, therefore, an object of the present invention to provide shift control apparatus and method for a hybrid transmission of a hybrid vehicle in which corrections for the drive torque command value and input revolution acceleration command value are made in such a manner that a combination of a target drive (or driving) torque and a target input revolution acceleration fall within a realizable region, the drive torque command value and input

revolution acceleration command value contribute to controls over the main power source (engine) and motor/generators so that a deterioration of the battery developed when the combination of the target

5   drive (driving) torque and the target input revolution acceleration which fall out of the realizable region contributes to the control over the main power source (engine) and the motor/generators is prevented from occurring, and which are capable of

10   eradicating the anxiety on the reduction in the shift quality by making this correction in such a way that the shift speed (input revolution acceleration) is not in the opposite direction to that in which the driver has expected to be directed

15   [0007]   According to one aspect of the present invention, there is provided a shift control apparatus for a hybrid transmission, comprising: a plurality of revolutional members which are enabled to be arranged on a predetermined lever diagram; a

20   differential unit having two degrees of freedom such that if revolution states of two revolutional members thereof are determined, the revolutional states of the other revolutional members are determined, an input of a main power source (ENG), an output to a

25   drive system, and a plurality of motor/generators (MG1, MG2) are coupled to the respective revolutional members of the differential unit to adjust a power from the motor/generators in such a manner that a shift ratio between the main power source and the

30   drive system is varied continuously; a target drive torque calculating section that calculates a target drive torque ($T*_{oo}$) to the drive system in accordance with a driving condition; a target input revolution

speed calculating section that calculates a target input revolution speed ($\omega*_E$) of one of the revolutional members which is coupled to the main power source (ENG); a target input revolution

5   acceleration calculating section that calculates a target input revolution acceleration (u_{io}) to converge an actual input revolution (ωi) into the target input revolution speed ($\omega*i$); and a target value correcting section that corrects at least one

10   of the target drive torque ($T*_{oo}$) and the target input revolution (u_{io}) to be a value within a realizable region to be set as a drive torque command value ($T*o$) and an input revolution acceleration command value (u_{io}) in such a manner that polarities

15   of the target drive torque ($T*_{oo}$) and the target input revolution acceleration (u_{io}) are left unchanged, in a case where a combination of the target drive torque with the target input revolution acceleration falls out of a realizable region on two-

20   dimensional coordinates of the drive torque and the input revolution acceleration related to a combination of the drive torque and the input revolution acceleration which is feasible in a state of the present motor/generators, a battery for the

25   motor/generators (MG1, MG2), and the main power source, the drive torque command value ($T*o$) and the input revolution acceleration command value (u_i) contributing to controls of the main power source and the motor/generators (3) in place of the target drive

30   torque ($T*_{oo}$) and the target input revolution acceleration (u_{io}).

[0008]   According to another aspect of the present invention, there is provided a shift control method for a hybrid transmission, the hybrid transmission comprising: a plurality of revolutional members which are enabled to be arranged on a predetermined lever diagram; and a differential unit having two degrees of freedom such that if revolution states of two revolutional members thereof are determined, the revolutional states of the other revolutional members are determined, an input of a main power source, an output to a drive system, and a plurality of motor/generators (MG1, MG2) are coupled to the respective revolutional members of the differential unit to adjust a power from the motor/generators in such a manner that a shift ratio between the main power source and the drive system is varied continuously, and the shift control method comprising: calculating a target drive torque ($T*o$) to the drive system in accordance with a driving condition; calculating a target input revolution speed ($\omega*_E$) of one of the revolutional members which is coupled to the main power source (ENG); calculating a target input revolution acceleration (u_{io}) to converge an actual input revolution (ωi) into the target input revolution speed ($\omega*i$); and correcting at least one of the target drive torque ($T*_{oo}$) and the target input revolution acceleration (u_{io}) to be a value within a realizable region to be set as a drive torque command value ($T*o$) or an input revolution acceleration command value (u_{io}) in such a manner that polarities of the target drive torque ($T*o$) and the target input revolution acceleration

(u_{io}) are left unchanged, in a case where a combination of the target drive torque (T*o) with the target input revolution acceleration (u_{io}) falls out of a realizable region on two-dimensional coordinates

5   of the drive torque (To) and the input revolution acceleration {$(d/dt)\omega i$} related to a combination of the drive torque and the input revolution acceleration which is feasible in a state of the present motor/generators, a battery (P_B) for the

10   motor/generators (MG1, MG2), and the main power source, the drive torque command value (T*o) and the input revolution acceleration command value (u_i) contributing to controls of the main power source (ENG) and the motor/generators (MG1, MG2) in place of

15   the target drive torque (T*$_{oo}$) and the target input revolution acceleration (u_{io}).

[0009]   This summary of the invention does not necessarily describe all necessary features so that the invention may also be a sub-combination of these

20   described features.

BRIEF DESCRIPTION OF THE DRAWINGS:

[0010]   Fig. 1A is an example of a diagrammatically illustrated hybrid transmission to which the present invention of a shift control apparatus in a first

25   preferred embodiment is applicable.

[0011]   Fig. 1B is a lever diagram of the hybrid transmission shown in Fig. 1A.

[0012]   Fig. 2 is a block diagram of a control system of the hydraulic transmission shown in Fig. 1A.

30   [0013]   Fig. 3 is a schematic functional block diagram of a hybrid controller in the control system shown in Fig. 2.

[0014]   Fig. 4 is a diagrammatical view representing a variable characteristic of the drive torque requested from the vehicle.

[0015]   Fig. 5 is a characteristic graph

5 representing an engine speed to develop an engine power with an optimum fuel economy.

[0016]   Fig. 6 is a diagrammatical view representing a realizable region illustrating a combination of a drive torque and an engine (input)

10 revolution acceleration by a combination of which is feasible by a battery rated power of the hybrid transmission.

[0017]   Figs. 7A, 7B, and 7C are diagrammatical views of a relationship between the feasible region

15 which is the same as that in the case of Fig. 6 and an operating point position during a non-shaft operation, of a relationship between the feasible region and the operating point position in which a movement state of the operating point during the

20 shift operation is a case wherein the operating point is still within the feasible region, and of a relationship between the feasible region and the operating point position in which the movement state of the operating point during the shift operation is

25 out of the realizable region.

[0018]   Fig. 8 is an operational flowchart representing a control program related to a correction procedure of a target drive (or driving) torque and a target engine (input) revolution

30 acceleration executed by a target value correcting section shown in Fig. 3.

[0019]   Fig. 9 is an operational flowchart representing a control program related to a

correction procedure of a target motor/generator torque executed by a motor/generator torque command value correcting section shown in Fig. 3.

[0020]   Fig. 10 is a regional diagrammatical view

5   illustrating an operable region of motor/generators.

[0021]   Fig. 11 is a diagram representing a correcting practice of the target motor/generator torques executed by motor/generator torque command value determining section shown in Fig. 3.

10   [0022]   Figs. 12A and 12B, representing a variation situation of a revolutional energy during the shift operation of the revolutional members in the hydraulic transmission and a diagram representing a relationship between the revolition energy and the

15   gear ratio and a variation rate with respect to the gear shift ratio of the revolution energy.

[0023]   Figs. 13A, 13B, 13C, and 13D are explanatory views of correction procedures of the target drive (or driving) torque and target engine (input)

20   revolution acceleration executed by the gear shift control apparatus in the hybrid transmission in a second preferred embodiment of the shift control apparatus according to the present invention, diagrammatical view illustrating an operating point

25   position during the no shift, diagrammatical view illustrating the movement state of the operating point during the shift operation which is still within the realizable region, and a diagrammatical view when the operating point is out of the feasible

30   region, and a diagrammatical view in a case where the movement state of the operating point of the shift is out of the realizable region to a degree that the operating point is out of the feasible region to a

degree which does not satisfy the shift speed lower limit value, respectively.

[0024]   Fig. 14 is an operational flowchart representing a control program related to the correction procedure of the target drive (or driving) torque and target engine (input) revolution acceleration executed by the shift control apparatus shown in Figs. 13A through 13D.

[0025]   Fig. 15 is an operational flowchart representing a control program related to the correction procedure.

[0026]   Fig. 16 is a diagrammatical view of a structure corresponding to Fig. 1A of the hybrid transmission in a third preferred embodiment of the shift control apparatus according to the present invention.

[0027]   Fig. 17 is a block diagram representing a control system of the hybrid transmission to which the shift control apparatus according to the present invention is applicable.

[0028]   Fig. 18 is a diagrammatical view of regions shown on a two-dimensional coordinate of the engine (input) revolution acceleration and the drive torque of a realizable region by means of motor/generators in the hybrid transmission shown in Fig. 16.

[0029]   Fig. 19 is a diagrammatical view representing an overlapped part of a realizable region of Fig. 18 and a realizable region of Fig. 6.

[0030]   Figs. 20A, 20B, and 20C are integrally a diagrammatical view of how a realizable region by means of the motor/generators shown in Fig. 18 is

varied when a maximum torque of the motor/generators is varied as 20A, 20B, and 20C.

[0031]   Fig. 21 is an operational flowchart representing a control program on a correction procedure of the target drive (or driving) torque and target engine (input) revolution acceleration executed by the shift control apparatus in a fourth preferred embodiment in the hybrid transmission shown in Fig. 16.

[0032]   Fig. 22 is a regional diagrammatical view representing the operable region of the motor/generators in the hybrid transmission shown in Fig. 16.

[0033]   Figs. 23A and 23B are characteristic diagrammatical views representing a maximum torque variation characteristics of first and second motor/generators MG1 and MG2 shown in Fig. 16, respectively.

[0034]   Fig. 24 is an operational flowchart representing a correction process program of the target drive (Or driving) torque and target engine (output) revolution acceleration in a fifth preferred embodiment of the shift control apparatus according to the present invention.

[0035]   Fig. 25 is an operational flowchart representing the correction process program of the target drive (driving) torque and target engine (input) revolution acceleration in a sixth preferred embodiment of the shift control apparatus according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS:

[0036]   Reference will hereinafter be made to the drawings in order to facilitate a better understanding of the present invention.

5   [0037]   (First Embodiment)

Fig. 1A shows a hybrid transmission to which a shift control apparatus in a first preferred embodiment according to the present invention is applicable. In the first embodiment, the hybrid transmission

10   constitutes a transaxle for a front-engine-front-drive (so called, FF) car. In Fig. 1A, a reference numeral 1 denotes a transmission casing in which a Ravigneaux type planetary gear set 2 located at a left side in an axial direction of transmission

15   casing 1 (leftward direction and rightward direction as viewed from Fig. 1A) is incorporated and a composite current two-layer motor 3 located at a right side in the axial direction of transmission casing 1 is incorporated. An engine (main power

20   source) ENG is disposed at an outside (leftward direction) of the transmission casing 1. Ravigneaux type planetary gear set 2, engine ENG, and composite current two-layer motor 3 is coaxially disposed on a main axial line of the hybrid transmission. In

25   transmission casing 1, a countershaft 6 and a differential gear unit 7 are juxtaposed to the main axial line with an offset and are also incorporated into transmission casing 1. Left and right driven road wheels 8 are drivingly coupled to differential

30   gear unit 7.

[0038]   Ravigneaux type planetary gear set 2 is a combination of two single pinion planetary gear groups 4 and 5 having a common pinion P2. One of the

planetary gear groups located nearer to engine ENG is a first single pinion planetary gear group 4 and the other of the planetary gear groups is a second pinion planetary gear group 5. First single pinion planetary

5   gear 4 is constituted by a sun gear S2 and a ring gear R2 to both of which a long pinion P2 are meshed. A second single pinion planetary gear group 5 is provided with a sun gear S1, a ring gear R1, and a large-diameter short pinion P1 meshed to both of the

10 sun gear S1 and ring gear R1. The short pinion P1 is meshed with a common pinion P2. In addition, pinions P1 and P2 of the planetary gear groups 4 and 5 are revolutionally supported by means of common carrier C.

15 [0039]   Ravigneaux type planetary gear set 2 has a main elements of four revolutional members of sun gear S1, sun gear S2, ring gear R2, and carrier C and is constituted by a differential unit 2 having the two degrees of freedom such that if the revolution

20 speeds of the two revolutional members are determined, the revolution speeds of the other members are determined. An order of revolution speed of the four revolutional members is sun gear (fastest) S1, ring gear R2, carrier C, and sun gear S2 as shown by a

25 lever diagram shown in Fig. 1B.
[0040]   Composite current two-layer motor 3 is constituted by an inner rotor 3ri, an annular outer rotor 3ro enclosing inner rotor 3ri, both rotors being revolutionally and coaxially supported within

30 transmission casing 1, a ring shaped stator 3s coaxially mounted in an annular stator 3s is fixedly mounted on transmission casing 1. Annular coil (stator) 3s and inner rotor 3ri constitutes a first

motor/generator MG1 and annular coil (stator) 3s and outer rotor 3ro constitutes a second motor/generator MG2. Each of motor/generators MG1 and MG2 functions as a motor which outputs individual direction and

5   velocity (including a stop)in accordance with a supply current when the composite current is supplied as a load and functions as a generator developing an electric power in accordance with a revolution by means of an external force.   As shown in the lever

10   diagram of Fig. 1B, in the revolution speed order from the four revolution speed members of Ravigneaux type planetary gear set 2, in the order of sun gear S1, ring gear R2, carrier C, and sun gear S2, first motor/generator MG1, the input from engine ENG which

15   is the main power source, and the output to the road wheel drive system (Out), and second motor/generator MG2 are coupled.

[0041]   If this connection is described in details in the following on the basis of Fig. 1A, ring gear

20   R2 serves as an input element to which the engine revolution is inputted as described above. A crankshaft of engine ENG is coupled to ring gear R2. Sun gear S1 is coupled to first motor/generator MG1 (rotor 4ri) via a hollow axle 11 extended toward a

25   rearward direction opposite to engine ENG. Sun gear S2 is coupled to motor/generator MG2 (rotor 4ro) via hollow axle 12 fitted to hollow axle 11 and motor/generator MG1 with a clearance.

[0042]   Carrier C serves as an output element on

30   which the revolution is outputted to the wheel drive system. An output gear 14 is coupled to carrier C via a hollow connecting member (output axle) 12. Output axle 14 is disposed between Ravigneaux type planetary

gear set 2 and composite current two-layer motor 3 and revolutionally (rotatably) supported within transmission casing 1. Output gear 14 is meshed with counter gear 15 on a countershaft 6. An output

5   revolution of transmission from output gear 14 is transmitted to differential gear unit 7 via counter gear 15 and via countershaft 6. Differential gear unit 7 distributes the output revolution from transmission into left and right driven wheels 8.

10   These elements described above constitute a road wheel drive system.

[0043]   The hybrid transmission whose structure has been heretofore described can be represented by the lever diagram shown in Fig. 1B. A lateral axis of

15   the lever diagram shown in Fig. 1B denotes a ratio of distances between the respective revolution members determined according to a gear ratio of the planetary gear of the planetary gear groups 4 and 5. That is to say, when the distance between ring gear R2 and

20   carrier C is 1, the ratio of distance between sun gear S1 and ring gear R2 is denoted by α and the ratio of distance between carrier C and sun gear S2 is denoted by β. A longitudinal axis of the lever diagram denotes a revolution speed of each

25   revolutional member. In details, an engine revolution speed ω_E to ring gear R2 (transmission input revolution speed ω_i), a revolution speed ω_1 of)motor/generator) sun gear S1, revolution speed ω_O of the transmission output (Out) from carrier C, and

30   revolution speed ω_2 of sun gear S2 (motor/generator MG2). If the revolution speeds of the two revolutional members are determined, the other two revolutional members are determined.

[0044]   A shift operation of the hybrid
transmission will hereinafter be described with
reference to the lever diagram shown in Fig. 1B. The
shift operation when a (vehicular) forward (positive)
5   revolution is outputted includes two modes of EV mode
and EIVT mode and a backward (reverse) revolution is
outputted includes a REV shift operation. In the EV
mode, as shown in lever EV shown in Fig. 1B, the
output (Out) to the road wheel drive system is
10   determined only by means of a power from both of
motor/generators MG1 and MG2 (or one of the
motor/generators) with engine ENG stopped. In the
EIVT mode, as illustrated in lever EIVT mode of Fig.
1B, the output (Out) to the road wheel drive system
15   is determined by means of the powers from engine ENG
and both of the motor/generators MG1 and MG2.
[0045]   The REV shift operation for the backward
(reverse) revolution output is not dependent upon the
power from engine ENG as shown by a lever REV in Fig.
20   1B but according to the positive revolution of the
one motor/generator MG1, or the reverse revolution of
the other motor/generator MG2, or both of the
motor/generators (MG1, MG2) revolution from carrier C
is outputted to output (Out).
25   [0046]   A shift control system of hybrid
transmission carrying out the shift operation control
in each mode described above is constituted as shown
in Fig. 2. A hybrid controller 21 performs an
integration control of both engine ENG and the hybrid
30   transmission. Hybrid controller 21 supplies commands
on target torque $T*_E$ and on target revolution speed
$(\omega*_E)$ (target input revolution speed $\omega*_1$) of engine
ENG to an engine controller 22. Engine controller 22

drives engine ENG to have engine ENG achieve this target values $T*_E$ and $\omega*_E$ ($\omega*_i$). Hybrid controller 21, furthermore, supplies command signals on target torques $T*_1$ and $T*_2$ of motor/generators MG1 and MG2 to

5 motor controller 23. Motor controller 23 controls motor/generators MG1 and MG2 by means of an inverter 24 and a battery 25 to achieve target torques $T*_1$ and $T*_2$. Hybrid controller 21 inputs a signal from an accelerator opening angle sensor 26 to detect an

10 accelerator opening angle APO from an accelerator pedal depression depth, a signal from a vehicle speed sensor 27 to detect a vehicle speed VSP (which is proportional to output revolution speed (= ωo), and a signal from an engine speed sensor 28 to detect the

15 engine speed ω_E (= input revolution speed, ω_i).

[0047] Hybrid controller 21 carries out a mode selection to achieve the driving state that the driver has desired from the accelerator pedal depression depth (accelerator opening angle) APO and

20 vehicle speed VSP, and a charged state of battery 25 (SOC state of charge (carrying out enabling power) and executes the shift control in accordance with the selection mode to determine and command the target engine torque $T*_E$, target engine speed $\omega*_E$ ($\omega*i$), and

25 target motor/generator torques $T*_1$ and $T*_2$.

[0048] It is noted that revolution speed information inputted to hybrid controller 21 is not limited to engine speed ω_E (ωi) and vehicle speed VSP (vehicle speed and output revolution speed ωo). Since

30 the differential unit constituted by Ravigneaux type planetary gear set 2 has two degrees of freedom, the

revolution speeds of any two of the revoltutional members may be inputted to hybrid controller 21.

[0049]   Fig. 3 shows a functional block diagram of hybrid controller 21. Hybrid controller 21 includes an input revolution servo controlling section 102, a target value correcting section 103, a motor/generator torque distributing section 104, a motor/generator torque command value determining section 105, and a target engine torque correcting section 106. Target value generating section 101 calculates a target driving torque $T*_{oo}$ to the road wheel drive system, a target engine revolution speed $\omega*_E$, and a target engine torque $T*_E O$ from an accelerator pedal depression depth (opening angle) APO, the vehicle speed VSP, and a battery charge state SOC (bringing out enabling power).

[0050]   Hence, at first, target driving torque $T*_{oo}$ to transmission output gear 14 is calculated using a drive torque map shown in Fig. 4 from accelerator depression depth (opening angle of the accelerator APO), vehicle speed VSP. Vehicle speed VSP is calculated using the following equation (1) from, for example, output axle revolution speed ωo.

$$VSP = k_v \cdot \omega o \quad \dots (1),$$ wherein kv denotes a constant determined according to a radius of a tire and a final gear ratio. Next, target value generating section 101 calculates a target driving power $P*o$ from target driving torque $T*o$ and output revolution speed ωo as follows: $P*o = \omega o \times T*o \quad \dots (2)$.

Next, target value generating section 101 determines a target battery charge-and-discharge quantity $P*_B$ in such a manner that, as SOC becomes high, the battery

discharge quantity becomes increased and, as SOC becomes low, the battery charge quantity becomes increased.

[0051]   Finally, target engine revolution speed $\omega*i$ and target engine torque $T*_{EO}$ are calculated as follows from target driving power $P*o$, engine speed ωi, and target battery charge-and-discharge quantity $P*_B$. The target engine power $P*_E$ is set in such a way that target engine power $P*_E$, target driving power $P*o$, and target charge-and-discharge quantity $P*_B$ have the relations expressed by the following equation: $P*_E = P*o + P*_B ...$ (3).

Next, target engine (revolution) speed $\omega*_E$ at which the fuel consumption becomes optimum when the target engine power $P*_E$ is generated by the engine is searched from target engine power $P*_E$ using a fuel consumption optimum target engine speed map shown in Fig. 5.

[0052]   In order to supply target engine power $P*E$ with the engine and to make an engine operating point a fuel consumption optimum point, there is a thought that a value of target engine power $P*_E$ divided by target engine revolution speed $\omega*_E$ should be target engine torque $T*_E$. However, target value correcting section 103 as will be described later often limits the 4engine (input) revolution acceleration during a shift transient state. In this case, target engine revolution speed $\omega*_E$ is not be realized. As described above, in a case wherein target engine revolution speed $\omega*_E$ is not realized, target engine power $P*_E$ cannot be obtained. Therefore, target engine torque

$T*_{EO}$ is a value of target engine power $P*_E$ divided by an actual engine (revolution) speed ω_I, as expressed by the following equation.

$$T_{EO}^* = \frac{P_E^*}{\omega_i} \cdots \quad (4).$$

5   **[0053]**   It is noted that if target engine revolution speed $\omega*_E$ is coincident with actual engine (revolution) speed ω_E during a steady state, the engine torque gives an engine torque whose fuel consumption is optimum. Referring to Fig. 3, an input

10   revolution servo controlling section 102 inputs a deviation between target engine revolution speed $\omega*_E$ and actual engine revolution speed ω_E and calculates a target engine (input) revolution acceleration u_{io} so that the deviation of the input revolution (engine

15   revolution) is decreased. When this calculation is carried out, target engine (input) revolution acceleration u_{io} may be calculated, for example, using a sliding mode controller as shown in the following equation.

20              $u_{io} = K\dfrac{\sigma}{|\sigma| + \varepsilon} \quad \cdots \quad (5).$

            $\sigma = \omega*_E - \omega i \quad \cdots \quad (6)$, wherein K denotes a constant determining an upper limit of target engine (input) revolution acceleration u_{io} and ε denotes a positive constant which makes target engine (input)

25   revolution acceleration u_{io} continuous in a proximity to zero of σ.

     [0054]   Referring to Fig. 3, target value correcting section 103 serves to correct target drive torque (or target driving torque) $T*_{oo}$ and target

30   engine (input) revolution acceleration u_{io} to a value

within the realizable region in a case where a combination of the drive torque To and engine (input) revolution acceleration dωi/dt (or expressed as {(d/dt)ωi} which can be realized under the present engine and state of the battery is expressed on two-dimensional coordinates shown in Fig. 6 with the drive torque To as a lateral axis and with an engine (input) revolution acceleration dω_i/dt as a longitudinal axis and the target drive (driving) torque T*$_{oo}$ and target engine (input) revolution acceleration dω_i/dt falls out of the realizable region expressed on two-dimensional coordinates shown in Fig. 6.

[0055]   A relationship from among drive torque To, engine (input) revolution acceleration dωi/dt, engine revolution speed ωi, output revolution speed ωo, running resistance torque T_R, engine torque T_E, and battery charge-and-discharge quantity P_B is expressed in the following equation (7).

$$\left(k_{ii}\omega_i + k_{io}\omega_o\right)\frac{d\omega_i}{ct} + \left(k_{oi}\omega_i + k_{00}\omega_o\right)T_o \;=\; k_R T_R \;+\; k_E T_E \;+\; P_B \;\ldots(7).$$

It is noted that k_{ii}, k_{io}, k_{oi}, k_{oo}, k_R, and k_E denote constants determined according to the specifications (inertia moment and radius of revolutional elements in the planetary gear unit of the hybrid system). In this equation (7), it is possible to detect the present engine speed ω_i and output revolution speed ωo are detectable and running resistance torque T_R and engine torque T_E can be estimated using, for example, an external disturbance observer. As shown in Fig. 6, with lateral axis as the drive torque To and longitudinal as engine

(input) revolution acceleration $d\omega i$, the two-dimensional coordinates is formed. From the range of battery charge-and-discharge quantity using the above equation (7), a region in which drive torque To and

5   engine (input) revolution acceleration $d\omega i/dt$ fall in a battery rated power (a realizable region) is obtained as shown in A of Fig. 6.

[0056] In this two-dimensional coordinate, suppose that a target operating point determined according to

10   target drive (or driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io}. If this target operating point falls out of the realizable region, target operating point does not fall within the battery rated power so that a life of the battery

15   becomes short. Hence, as described below, signs of these target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} is corrected within the value of the realizable region to define a drive torque command value $T*_o$ and target

20   engine (input) revolution acceleration u_i. A method of correcting target drive (driving) torque $T*_{oo}$ and target revolution acceleration u_{io} will be described below with reference to Figs. 7A, 7B, and 7C.

[0057] In Figs. 7A, 7B, and 7C, a target operating

25   point expressed by the combination of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} before the correction is denoted by o (circle in white) and a command operating point expressed as a combination of a drive

30   torque command value $T*_o$ and target engine (input) revolution acceleration u_i after the correction of

these physical values is made is denoted by • (circle
in black).

[0058]   Target operating point ? shown in Fig. 7A
indicates a running state at a certain target drive
5   (driving) torque $T*_{oo}$ without shift (engine (input)
revolution acceleration $d\omega i/dt = 0$). After this,
when accelerator pedal is depressed, target operating
point ? of Fig. 7A is moved to a broken line denoted
by Fig. 7B. In Fig. 7B, since target operating point
10 is present within the realizable region A, the
corrections for target drive (driving) torque $T*_{oD}$
and target engine (input) revolution acceleration u_{io}
is not carried out.

[0059]   Thereafter, when target operating point o
15 is moved furthermore as denoted by a broken line in
Fig. 7C, target operating point o becomes out of
realizable region A and the combination of target
drive (driving) torque $T*_{oo}$ and target engine
acceleration u_{io} cannot be realized which is fastest
20 responded cannot be achieved but also becomes out of
the battery rated power so that the life of the
battery becomes introduced.   In this case, target
value correcting section 103, in the two-dimensional
coordinates of drive torque To and engine (input)
25 revolution acceleration $d\omega i/dt$ shown in Fig. 7C,
assumes the point of circle black • nearest to the
target operating point o which is on a line segment
denoted by a solid line connecting between the origin
on the two-dimensional coordinate and target
30 operating point o corresponding to the combination of
target drive (driving) torque $T*_{oo}$ and target engine
(input) revolution acceleration u_{io}. Then, target

value correcting section corrects target drive (driving) torque $T*_{oo}$ and target engine acceleration u_{io} at the target operating point ? to drive torque $T*o$ and engine (input) revolution acceleration u_i at command operating point • and these corrected drive torque $T*o$ and engine (input) revolution acceleration u_i is set as the drive torque command value and engine acceleration command value and commanded to motor/generator torque distributing section 104.

[0060]   Target value correcting section 103 executes the correction process of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} (determination of drive torque command value $T*o$ and engine (input) revolution acceleration command value u_i) in accordance with a flowchart shown in Fig. 8.

[0061]   At a step S10, target value correcting section 103 derives realizable region A expressed on the two-dimensional coordinate of drive torque To and engine (input) revolution acceleration $(d/dt)\omega i$ shown in Figs. 6 and 7 and two boundary lines prescribing this region. These two boundary lines can be calculated in the following equation in which PB in equation (7) is replaced with a battery rated power $\pm P_{Bmax}$.

[0062]

$$(k_{ii}\omega_i + k_{io}\omega_o)\frac{d\omega_i}{dt} + (k_{oi}\omega_i + k_{oo}\omega_o)T_0 = k_R T_R + k_E T_E + P_{B\max} \dots (8).$$

$$(k_{ii}\omega_i + k_{io}\omega_o)\frac{d\omega_i}{dt} + (k_{oi}\omega_i + k_{oo}\omega_o)T_o = k_R T_R + k_E T_E - P_{B\max} \dots (9).$$

[0063]   At step S11, target value correcting
section 103 derives points of intersections (x_1, y_1)
and (x_2, y_2) of a straight line denoted by a bold
solid line shown in Fig. 7C, passing through target
operating point o which is the combination of target
drive (driving) torque x_0 (= T^*_{oO}) and target engine
(input) revolution acceleration y_0 (= u_{io}) expressed
in the equation (9) and an origin 0 of the two-
dimensional coordinates and boundary lines calculated
from the above equations (8) and (9) (wherein $x_1 < x_2$
and x_1 and x_2 denote drive torques and y_1 and y_2
denote engine (input) revolution accelerations).

$$\frac{d\omega_i}{dt} = \frac{u_{io}}{T^*_{oO}} T_o \cdots \quad (10).$$

[0064]   At a step S12, target value correcting
section 103 determines whether x_0 falls between x_1
and x_2. If xo is determined to be within x_1 and x_2
(yes), the routine goes to a step S13 since target
drive (driving) torque T*o and target engine (input)
revolution acceleration u_{io} falls within a realizable
region A. If x_0 is determined not to fall within x_1
and x_2 (no), the control goes to a step S14 since
target drive (driving) torque and target engine
(input) revolution acceleration is out of realizable
region A.

[0065]   At step S13 selected when the above-
described target drive (driving) torque and target
engine (input) revolution acceleration fall within
the realizable region A, target operating point o
which is the combination of target drive (driving)
torque xo (= T^*_{oD}) and target engine (input)
revolution acceleration y_0 (= U_{io}) is directly set as

the post-correction drive torque command value T_o* and target drive engine (input) revolution acceleration u_{io} is directly set as the post-correction engine (input) revolution acceleration u_i.

5   At step S14 selected when the above-described target drive (driving) torque and target engine (input) revolution acceleration do not fall within realizable region A. The operating points of one of both of $(x_1$. $y_1)$ and (x_2, y_2) which is nearer to (x_0, y_0) is served

10   as the command operating point and the drive torque T_{*o} and engine (input) revolution acceleration u_i are respectively set as the post-correction drive torque command value T_{*o} and the post-correction engine (input) revolution acceleration command value u_i.

15   Hence, post-correction drive torque command value $T*o$ and post-correction engine (input) revolution acceleration value u_i have the same sign (polarity) as target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io}.

20   **[0066]**   Referring back to Fig. 3, motor/generator torque distributing section 104 determines target torques (target motor/generator torques) $T*_{10}$ and $T*_{20}$ of motor/generators MG1 and MG2 to achieve post-correction drive torque command value $T*o$ and post-

25   correction engine (input) revolution acceleration command values u_i (transmission command value) even in the steady state nor in the transient state. To determine this target torques $T*_{10}$ and $T*_{20}$, the following relationship is established from among

30   engine (input) revolution acceleration $d\omega_i/dt$, running resistance torque T_R, engine torque T_E, and

the relationship between torques T_1 and T_2 of motor/generators MG1 and MG2.

$$\frac{d\omega_i}{dt} = b_{11}T_R + b_{12}T_E + b_{13}T_1 + b_{14}T_2 \ldots \quad (11).$$

[0067]   In addition, the following relationship is established from among drive torque To, running resistance torque T_R, engine torque T_E, and motor/generator torques T_1 and T_2 are established.

$$T_0 = b_{21}T_R + B_{22}T_E + b_{23}T_1 + b_{24}T_2 \quad \ldots (12).$$

When equation (11) and equation (12) are combined, the following equation is established.

$$\begin{bmatrix} T_1 \\ T_2 \end{bmatrix} = A_c^{-1}\left(\begin{bmatrix} d\omega_i/dt \\ T_0 \end{bmatrix} - B_c\begin{bmatrix} T_R \\ T_E \end{bmatrix}\right) \quad \ldots \quad (13).$$

$$A_C = \begin{bmatrix} b_{13} & b_{14} \\ b_{23} & b_{24} \end{bmatrix}, \quad B_c = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

If, in equation (13), drive torque To is replaced with post-solution drive torque command value T*o, target engine (input) revolution acceleration $(d/dt)\omega_i$ is replaced with post-correction engine revolution command value u_i, furthermore, torques T_1 and T_2 of motor/generators MG1 and MG2 are replaced with target motor/generator torques T*$_{10}$ and T*$_{20}$, the following equation is obtained, the following equations are obtained. From this equation, target motor/generator torques T*$_{10}$ and T*$_{20}$ can be obtained.

$$\begin{bmatrix} T_{10}^* \\ T_{20}^* \end{bmatrix} = A_c^{-1}\left(\begin{bmatrix} u_i \\ T_0^* \end{bmatrix} - B_c\begin{bmatrix} T_R \\ T_E \end{bmatrix}\right) \quad \ldots \quad (14).$$

It is noted that, running resistance torque T_R and engine torque T_E may directly be detected or, alternatively, may be estimated using an external disturbance observer. In either case, these running

resistance torque T_R and engine torque T_E may easily be determined.

[0068]   A motor/generator torque command value determining block 105 in Fig. 3 determines motor/generator torque command values $T*_1$ and $T*_2$ by correcting target motor/generator torques $T*_{10}$ and $T*_{20}$ to values within the torque range in which target motor/generator torques $T*_{10}$, $T*_{20}$ can be outputted in a case where each target motor/generator torques $T*_{10}$ and $T*_{20}$ obtained by motor/generator torque distributing section 104 as described above is in excess of a mechanically output enabled torque range and in a case where the achieved target motor/generator torque $T*_{10}$ and $T*_{20}$ is in excess of the battery rated power.

[0069]   Thus, motor/generator torque command value determining section 105 limits motor/generator torques $T*_{10}$ and $T*_{20}$ within an output enabled torque range and limits the same target motor/generator torques to become excessive with respect to the battery rated power. These limitations serve to function to protect a earlier deterioration of motor/generators MG1 and MG2 and to protect a demand exceeding the battery rated power from deteriorating the battery at an early timing.

[0070]   One example of an algorithm executed by motor/generator torque command value determining section 105 in which target motor/generator torques $T*_{10}$, $T*_{20}$ are corrected to values within the output enabled operating enabling (operable) range to determine motor/generator torque command value $T*_1$

and $T*_2$ will be described in details with reference
to an operational flowchart shown in Fig. 9.

[0071]   At a step S20, motor/generator torque
command value determining section 105 determines
5 whether each of target motor/generator toques $T*_{10}$
and $T*_{20}$ is within the mechanically output enabled
torque range and is within the operable region not
exceeding the battery rated power.

[0072]   The operable region of target
10 motor/generator torques $T*_{10}$ and $T*_{20}$ will be
described with reference to two-dimensional
coordinates of Fig. 10, with torque T_1 of first
motor/generator taken along a lateral axis of Fig. 10
and torque T_2 of second motor/generator MG2 taken
15 along a longitudinal axis of Fig. 10.

[0073]   In details, the following relationship is
established from among battery charge-and-discharge
quantity P_B, revolution speed ω_1 and torque T_1 of
first motor/generator MG_1, and revolution speed ω_2
20 and torque T_2 of second motor/generator MG_2.

$$P_B = \omega_1 T_1 + \omega_2 T_2 \quad ... (15).$$

[0074]   It is noted that the present engine
(revolution) speed ω_1 and output revolution speed ω_o
are detectable. Using equation (15), a region FA
25 which is a region in which the drive torque and
engine revolution speed fall within the battery rated
power from the range of battery charge-and-discharge
quantity P_B is obtained as shown in Fig. 10. Next, a
mechanical operation range of composite current two-
30 layer motor 3 can be determined as a region FB shown
in Fig. 10 as appreciated from the following
explanation.   That is to say, in the case of

composite current two-layer motor 3, the following

relationship is present between revolution speeds ω_1

and ω_2 of the first and second motor/generators MG1

and MG2 and mechanical torque maximum values T_{1max} and

5   T_{2max}. Torque maximum value T_{1max} of first

motor/generator MG1 is expressed by a non-linear

function f_1 of torque maximum value T_{2max} of second

motor/generator MG2 and of revolution speeds ω_1 and

ω_2 of both motor/generators MG1 and MG2.

10           $T_{1max} = f_1(T_{2max}, \omega_1, \omega_2)$ ...(16).

Using equation (16), from the present revolution

speeds ω_1 and ω_2 of first and second motor/generators

MG1 and MG2, a relationship between mechanical torque

maximum values T_{1max} and T_{2max} of first and second

15   motor/generators MG1 and MG2 is obtained. From this

relationship, a mechanical operation range of

composite current two-layer motor 3 can be obtained

as denoted by region FB of Fig. 10.

[0075]   Furthermore, in order to prevent engine

20   (input) revolution acceleration (shift speed) from

being placed in the proximity to zero by a

predetermined value y_{min} when target motor/generator

torques $T*_{10}$ and $T*_{20}$ are corrected, a torque range of

first and second motor/generators MG1 and MG2 at a

25   time when engine (input) revolution acceleration

indicates a value toward the engine revolution speed

acceleration side than the predetermined value y_{min} at

a time when the ante-correction target

motor/generator torques $T*_{10}$ and $T*_{20}$ are achieved is

30   determined as a region FC in Fig. 10. This region FC

is set using equation (11) so as to satisfy the

following conditions.

If $b_{11}T_R + b_{12}T_E + b_{13}T*_{10} + b_{14}T*_{20} \geq 0$, $b_{11}T_R +$ $b_{12}T_E + b_{13}T_1 + b_{14}T_2 \geq y_{min}$ ... (17).

If $b_{11}T_R + b_{12}TE + b_{13}T*_{10} + b_{14}T_2 \leq 0$, $b_{11}T_R +$ $b_{12}T_E + b_{13}T_1 + b_{14}T_2 \leq y_{min}$ ...(18). It is noted that the above-described predetermined value y_{min} may be set as follows:

$$y_{min} = ky \frac{\sigma_y}{\left[\sigma_y\right] + \varepsilon_y} \text{...(19),}$$

wherein σ_y: a deviation between target input revolution speed and actual input revolution speed, εy: a positive constant to make continuous y_{min} when $\sigma_y = 0$, and Ky denotes a positive constant obtained by experiments or computer simulation.

[0076]   A region FX on which the above-described region FA in the two-dimensional coordinate, region FB, and region FC are overlapped, on the two-dimensional coordinates of both of motor/generator torques shown in Fig. 10 is the above-described operable region. In a case where three conditions described below are satisfied, target motor/generator torques $T*_{10}$, $T*_{20}$ fall in the operable region FX.

(Condition 1)

The battery charge-and-discharge quantity P_B obtained by substituting target motor/generator torques $T*_{10}$ and $T*_{20}$ into equation (15) is equal to or below a battery rated power.

(Condition 2)

Target motor/generator torque $T*_{10}$ is smaller than torque maximum value T_{1max} of first motor/generator MG1 obtained by substituting target motor/generator torques $T*_{20}$ into equation (16) and target

motor/generator torque $T*_{20}$ is smaller than torque maximum value T_{2max} of motor/generator torque MG2 obtained by substituting target motor/generator torque T_{*10} into equation (16).

5 (Condition 3)

If $b_{11}T_R + b_{12}T_E + b_{13}T*_{10} + b_{14}T*_{20} \geq 0$, target motor/generator torques $T*_{10}$ and $T*_{20}$ satisfy the relationship of equation (17) and, if $b_{11}T_R + b_{12}T_E + b_{13}T*_{10} + b_{14}T*_{20} \leq 0$, target/motor generator torques

10 $T*_{10}$ and $T*_{20}$ satisfy the equation (18).

[0077] At a step S20 in Fig. 9, motor/generator torque command value determining section 105 determines whether the above-described three conditions are satisfied and both of target

15 motor/generator torques $T*_{10}$ and $T*_{20}$ fall within operable region FX shown in Fig. 10.

If both of target motor/generator torques $T*_{10}$ and $T*_{20}$ fall within the operable region FX at step S20, the routine goes to a step S21. At step S21,

20 motor/generator torque command value determining section 105 directly sets target motor/generator torques $T*_{10}$ and $T*_{20}$ without correction as motor/generator torque command values $T*_1$ and $T*_2$.

If target motor/generator command values $T*_{10}$ and $T*_{20}$

25 are out of operable region FX, at a step S22, motor/generator torque command value determining section 105 corrects target motor/generator torques $T*_{10}$ and $T*_{20}$ to values within operable region FX in such a manner that a variation of the drive torque is

30 minimized and sets the corrected target

motor/generator torques $T*_{10}$ and $T*_{20}$ as

motor/generator torque command values $T*_1$ and $T*_2$.

[0078]   The correction procedures carried out at

steps S21 and S22 of Fig. 9 for target

5   motor/generators $T*_{10}$ and $T*_{20}$ will hereinafter be

described on the basis of Fig. 11 in which operable

region FX is extracted from Fig. 10.

[0079]   In Fig. 11, o denotes an ante-correction

operating point which is a combination of target

10   motor/generator torques $T*_{10}$ and $T*_{20}$ which are before

the correction processing and • denotes a post-

correction operating point which is a combination of

motor/generator torque command values of $T*_1$ and $T*_2$.

A straight line passing through ante-correction

15   operating point o indicates the combination of

motor/generator torques T_1 and T_2 which develops the

same drive torque as drive torque To which can be

obtained from equation (12) achievable according to

the realization of ante-correction target

20   motor/generator torque command values $T*_{10}$ and $T*_{20}$.

[0080]   Patterns on the correction procedures of

target motor/generator torques $T*_{10}$ and $T*_{20}$ are three

patterns of pattern A, pattern B, and pattern C.

Individual patterns thereon will be described below.

25   << Pattern A >>

This pattern is a case where the ante-correction

operating point o (target motor/generator torques $T*_{10}$

and $T*_{20}$) is present in operable region FX.   In this

case, as described above with reference to step S21

30   of Fig. 9, target motor/generator torques $T*_{10}$ and

$T*_{20}$ are not corrected and these are set directly as

the post-correction motor/generator torque command values $T*_1$ and $T*_2$.

<< Pattern B >>

Pattern B is a case where ante-correction operating point o (target motor/generator torques $T*_{10}$ and $T*_{20}$) is out of operable region FX but an equi(equivalent)-drive torque straight line passing through the ante-correction operating point o is intersected across operable region FX. In this case, at step S22 of Fig. 9, operating point • nearest to ante-correction operating point o and which is on the equi-drive torque straight line passing through the ante-correction operating point o and falls within the operable region FX is set as a post-correction operating point. The motor/generator torque command values T_1 and T_2 at this post-correction operating point ? are post-correction motor/generator torque command values $T*_1$ and $T*_2$. In this case, the drive torque is not changed even by the correction of target motor/generator torques $T*_{10}$ and $T*_{20}$ which (motor/generator torque command values $T*_1$ and $T*_2$).

<<Pattern C >>

Pattern C is a case where ante-correction operating point o (target motor/generator torques $T*_{10}$, $T*_{20}$) falls out of operable region FX and the equi-drive torque straight line is not intersected with the operable region FX. In this case, the operating point which can generate the same drive torque as the drive torque obtained by the achievement of ante-correction target motor/generator torques $T*_{10}$ and $T*_{20}$ is not present, Therefore, at step S22 of Fig. 9, the operating point ? which is within the operable region

FX and which is nearest to the equi-drive torque straight line passing through ante-operating point o is set as the post-correction operating point. The correction of target motor/generator torques $T*_{10}$ and

5     $T*_{20}$ are corrected so that motor/generator torques T_1 and T_2 at this post-correction operating point ? is set as the post-correction motor/generator torque command values $T*_1$ and $T*_2$. In this case, the variation in the drive torque along with the

10   correction of target motor/generator torques $T*_{10}$ and $T*_{20}$ (motor/generator torque command values $T*_1$ and $T*_2$) can be suppressed at minimum.

[0081]   According to the corrections of target motor/generator torques $T*_{10}$ and $T*_{20}$ described above,

15   if the combination of target torques $T*_{10}$ and $T*_{20}$ of both motor/generators MG1 and MG2 (ante-correction operating point o in Fig. 11), as described in pattern A and pattern C, is out of operable region FX determined according to the rated power of the

20   battery and the capabilities of motor/generators MG1 and MG2, this combination is corrected to the value within operable region FX to provide a combination of motor/generator torque command values $T*_1$ and $T*_2$ (post-correction operating point • of Fig. 11). This

25   combination contributes on the control over motor/generators. Therefore, drive commands which exceed the capabilities of motor/generators MG1 and MG2 themselves and the rated power of the battery are not received. Consequently, reductions of the life of

30   the battery and of durability of motor/generators MG1 and MG2 can be avoided.

[0082] When the corrections of target motor/generators $T*_{10}$ and $T*_{20}$ are carried out, the corrections are made so that the polarities of the drive torque and engine (input) revolution

5 acceleration according to the post-correction motor/generator torque command values $T*_1$ and $T*_2$ are the same as the drive torque and engine (input) revolution acceleration by means of ante-correction target motor/generator torques $T*_{10}$ and $T*_{20}$. The

10 generation of the drive torque and the engine (input) revolution acceleration which are opposite to the desired drive torque and the desired engine (input) revolution acceleration by means of the ante-correction target motor/generator torques can be

15 avoided. An unnatural variation in the drive torque and shift speed can be prevented and unpleasant vehicular acceleration/deceleration and the problems on the transmission quantity having the sense of incompatibility can be eliminated.

20 [0083] When the corrections of target motor/generator torques $T*_{10}$ and $T*_{20}$ are made, motor/generator torque command values $T*_1$ and $T*_2$ are determined to be the same value as the driving torque obtained by the drive torque by means of ante-

25 correction target motor/generator torques $T*_{10}$ and $T*_{20}$ or the value within the region which is nearest to the drive torque described above. Hence, even if the correction of target motor/generator torques $T*_{10}$ and $T*_{20}$ is made, the variation in the drive torque

30 is present or an unpleasant vehicular acceleration/deceleration feeling can be eliminated

with at least the variation in the drive torque minimized.

[0084]   In addition, when target motor/generator torques $T*_{10}$ and $T*_{20}$ are corrected, within a region of the two-dimensional coordinates of T_1 and T_2 in which the engine (input) revolution acceleration $d\omega i/dt$ (shift speed) indicates a value toward which the ante-correction revolution acceleration side than predetermined value y_{min} between 0 and ante-correction revolution acceleration obtained by the ante-correction target motor/generator torques $T*_{10}$ and $T*_{20}$, the correction is carried out so that a difference between the drive torques before and after the corrections of target motor/generator torques $T*_{10}$ and $T*_{20}$ is minimized and the target motor/generator torques $T*_{10}$ and $T*_{20}$ are corrected to be set as motor/generator torque command values $T*_1$ and $T*_2$.   Hence, the variation of the drive torque is minimized so that an unpleasant vehicular acceleration or deceleration feeling can be suppressed with the shift speed faster than predetermined value y_{min} maintained even if target motor/generator torques $T*_{10}$ and $T*_{20}$ are corrected.

[0085]   Referring back to Fig. 3, target engine torque correcting section 106 serves to correct target engine torque $T*_{EO}$ in such a manner that a power needed to the gear shift is provided from the engine. The following relationship is present from among a power Pi required for the revolution speed variation of the revolutional members constituting the power transmission mechanism, engine power P_E, motor/generator power P_B, and drive power Po.

$$P_E + P_B = P_i + P_o \quad ...(20).$$

Hence, even when the revolution speed of any revolutional member in the hybrid transmission such as during the shift operation, it is necessary to supply the power needed for the gear shift by means of engine ENG or motor/generators MG1 and MG2 in order to achieve the target drive (driving) torque.

[0086] However, since motor/generator power P_B is equal to battery charge-and-discharge quantity, a load on the battery is increased when the power required for the shift by means of motor/generators MG1 and MG2 and there is a possibility that the increase of the load exceeds the battery rated power. Because motor/generators MG1 and MG2 compensates for the lack of engine power due to a lag with respect to the target value of the engine torque. Therefore, the power required for the shift is supplied from the engine. It is noted that, as in the case of the hybrid transmission in the first embodiment, the power from a plurality of power sources using the differential unit constituted by the planetary gear mechanism is outputted to the drive axle, a revolutional system kinetic energy as conventional transmission is often not monotonously varied according to the gear ratio depending upon a specification of the hybrid transmission.

[0087] The relationship between the gear shift ratio i_c of the hybrid transmission and kinetic energy U is as shown in Fig. 12A. The revolutional kinetic energy U takes a minimum value at a certain predetermined gear ratio i_{co}. Hence, in the conventional transmission, although the sign of the revolution kinetic energy variation is the same

provided that the direction of the shift is constant,
In the case of the hybrid transmission, even if the
shift direction is constant, the direction of the
revolutional kinetic energy variation   is changed
5   with a shift ratio of i_{c0} as a boundary, as shown in
Fig. 12B. Therefore, in a case where the engine
serves to compensate for the required power, a sign
of a compensation quantity is needed to be reversed
with the shift ratio of i_{c0} as a boundary. Herein,
10   the compensation quantity when the power required for
the gear shift is provided by the engine is
calculated.   The kinetic energy U of the revolutional
system of the hybrid transmission can be expressed in
the following equation.

15
$$U = \sum_{j=1}^{n} \frac{1}{2} I_j \omega_j^2 \dots (21),$$

Wherein n denotes the number of revolutional members
in the hybrid transmission.   If the kinetic energy U
described in equation (21) is differentiated with
respect to time, the following equation can be
20   obtained,

$$dU/dt = \sum_{j=1}^{n} I_j \omega_j \dots (22).$$

[0088]   In equation (22), the revolution speed of
each revolutional member due to the constraint of the
revolution speeds of the planetary gear mechanism is
25   given by a linear coupling between engine revolution
speed ωi and output revolution speed ωo.

$$dU/dt =$$
$$\left(m_{ii} \frac{d\omega_i}{dt} + m_{oi} \frac{d\omega_o}{dt} \right) \omega i_i + \left(m_{io} \frac{d\omega_i}{dt} + m_{oo} \frac{d\omega_o}{dt} \right) \omega_o \dots (23).$$

In equation (23), m_{ii}, m_{io}, m_{oi}, and m_{oo} denotes constants determined according to the specifications of the hybrid transmission.

[0089]   dU/dt expressed in equation (23) is a power Pi required for the shift and dωi/dt in equation (23) is the post-correction target engine revolution speed, or obtained from equation (11), or dω$_o$/dt can be obtained from the following equation (24).

$$\frac{d\omega_o}{dt} = b_{11}'T_R + b_{21}'T_E + b_{13}'T_1 + b_{14}'T_2 \quad \dots(24).$$

In equation (24), b'_{21}, b'_{22}, b'_{23}, and b'_{24} denote constants determined according to the specifications of the hybrid transmission. Target engine torque T*EO is corrected as follows to determine engine torque command value T*$_E$ in order to provide the engine for the power required for the shift.

$$T*_E = T*_{EO} + \frac{p_i}{\omega_i} \quad \dots(25).$$

If equation (25) is used, the sign of compensation quantity of the power required for the shift is automatically changed with the shift ratio i_{co} as a boundary. The shift ratio i_{co} is determined using equation (23). As expressed in the following equation (26), the shift ratio when dU/dt = 0 is a kinetic energy minimum gear shift ratio i_{co}.

$$i_{co} = -\frac{m_{ii}\dfrac{d\omega_i}{dt} + m_{oi}\dfrac{d\omega_o}{dt}}{m_{io}\dfrac{d\omega_i}{dt} + m_{oo}\dfrac{d\omega_o}{dt}} = -\frac{m_{ii} + m_{oi}\dfrac{d\omega_o}{d\omega_i}}{m_{io} + m_{oo}\dfrac{d\omega_o}{d\omega_i}} \quad \dots(26).$$

As expressed in equation (26), kinetic energy minimum shift ratio i_{co} is dependent upon input revolution acceleration dω$_i$/dt and output revolution acceleration dω$_o$/dt. However, during the shift at

which the power required for the shift becomes large,
the following assumption can be made:

$d\omega_o/d\omega_i \cong 0$ ... (27).

Using equation (26), kinetic energy minimum gear

5   shift ratio i_{co} may be the constant.

$$i_{co} = -\frac{m_{ii}}{m_{io}} \quad ... (28).$$

In a case of the hybrid transmission in which   an
engine clutch which is clutched or released between
engine ENG and hybrid transmission, each value of m_{ii},

10   m_{io}, m_{oi}, and m_{oo} is different dependent upon the
clutch state and release state. Consequently, as
appreciated from equations (26) and (28), kinetic
energy minimum shift ratio i_{co} is different depending
upon the clutched state of engine clutch.

15   **[0090]**   In the first embodiment of the shift
control apparatus, as described above with reference
to Fig. 7C and Fig. 8 (step S14), if the combination
of target drive (or driving) torque $T*_{oo}$ and target
engine (input revolution acceleration u_{io} is out of

20   realizable region A, these target drive (driving)
torque $T*_{oo}$ and target engine (input) revolution
acceleration u_{io} are corrected so as to change the
values within realizable region A and to be set as
drive torque command value $T*_{oo}$ and engine (input)

25   revolution acceleration command value u_i to
contribute to controls of engine ENG and
motor/generators MG1 and MG2. Hence, an earlier
deterioration of the battery developed in the case
where target drive (driving) torque $T*_{oo}$ and target

30   engine (input) revolution acceleration u_{io} which are
out of realizable region A directly contribute on the

controls of engine ENG and motor/generators MG1 and
MG2 can be prevented.

[0091]   Then, when target drive (driving) torque
$T*_{oo}$ and target engine (input) revolution

5 acceleration u_{io} are corrected to the values within
realizable region A, both signs (polarities) of the
corrected drive torque command value $T*_o$ and engine
(input) revolution acceleration command value u_i are
not changed from those of target drive (driving)

10 torque $T*_{oo}$ and target engine (input) revolution
acceleration u_{io}. Hence, if post-correction drive
torque command value $T*_o$ and engine (input)
revolution acceleration command value u_i are used for
the controls of engine ENG and motor/generators MG1

15 and MG2, the shift speed (engine (input) revolution
acceleration) is not reversed in the opposite
direction that the driver has expected, the situation
in which the input revolution speed change which is
opposite to the driver's expectation from the driving

20 operation occurs can be avoided, and the anxiety such
that the shift gives unpleasant feeling to the driver
can be eliminated.

[0092]   (Second Embodiment)
Figs. 13A through 13D and Fig. 14 show a correction

25 processing on the target drive (driving) torque and
target engine (input) revolution acceleration of the
shift control apparatus in a second embodiment
according to the present invention. Figs. 13A through
13D and Fig. 14 correspond to the realizable region

30 diagrams and flowchart of Figs. 7A through 7C and Fig.
8.
In the second embodiment, since the structure of the
hybrid transmission, the shift control system, and

block diagrams dependent on the shift control
function are the same as those of the first
embodiment shown in Figs. 1 through 3, the
explanations thereof will herein be omitted. Only the
5   correction method of target drive (driving) torque
T*$_{oo}$ and target engine acceleration u$_{io}$ will be
explained with reference to the realizable region
diagram in Figs. 13A through 13D and with reference
to the control program shown in Fig. 14.
10   [0093]   In Figs. 13A, 13B, 13C, and 13D, the target
operating point represented by ante-correction target
drive (driving) torque T*$_{oo}$ and target engine (input)
revolution acceleration u$_{io}$ are denoted by the white
circle ? and the command operating point represented
15   by the post-correction drive torque command value T*o
and target engine (input) revolution acceleration u$_i$
is denoted by the black circle •. Target operating
point o shown in Fig. 13A indicates a running state
without the shift by a certain target drive (driving)
20   torque T*$_{oo}$ (engine (input) revolution acceleration
(d/dt)ωi = 0). Thereafter, when the accelerator pedal
is depressed, target operating point o is moved as
denoted by a broken line of Fig. 13B. However, since
target operating point o is placed within realizable
25   region A in Fig. 13B, the correction of target derive
torque T*$_{oo}$ and target engine (input) revolution
acceleration u$_{io}$ is not carried out. Thereafter, when
target operating point o is furthermore moved as
denoted by a broken line shown in Fig. 13C, target
30   operating point o is out of realizable region A so
that the combination of target drive (driving) torque
T*$_{oo}$ and target engine (input) revolution

acceleration u_{io} which correspond to earliest cannot only be achieved but also does not fall within the rated power of the battery. Consequently, the reduction of the life of the battery is introduced.

5 In this case, target value correcting section 103, on the two-dimensional coordinate of drive torque To and two-dimensional coordinate of engine (input) revolution acceleration $(d/dt)\omega i$ shown in Fig. 13C, derives in the following way command operating point

10 • on the basis of target operating point o corresponding to the combination of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io}. Then, target value correcting section 103 sets drive torque $T*o$ and

15 engine (input) revolution acceleration u_i at this command operating point • as the drive torque command value and the engine (input) revolution acceleration command value.

[0094] When command operating point • is

20 determined, since a degree of requirement of the achievement of target drive (driving) torque $T*_{oo}$ is higher than target engine (input) revolution acceleration u_{io} particularly when such a shift that both of target driver torque $T*_{oo}$ and target engine

25 (input) revolution acceleration u_{io} are abruptly varied occurs. Hence, target drive (driving) torque $T*_{oo}$ is not corrected but is directly set as drive torque command value $T*_{o}$ but engine (input) revolution acceleration u_{io} is corrected. Thus,

30 target operating point o which corresponds to the combination of target drive (or driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io}

is moved by a minimal displacement within realizable region A. At this time, a point • to which above described point ? is moved by minimal displacement is set as command operating point. In more details, a

5   point • which is nearest to target operating point o, which is within realizable region A, and which is on a line segment (a line segment by which target drive (or driving) torque $T*_{oo}$ is maintained) passing through target operating point o corresponding to the

10   combination of target drive (driving) torque $T*_{oo}$ and target engine (input)revolution acceleration u_{io} and denoted by a dot-and-dash line parallel to an engine (input) revolution acceleration axis which is a longitudinal axis of Fig. 13C is the command

15   operating point. The drive torque $T*o$ and engine (input) revolution acceleration u_{io} at this point of • is set as the drive torque command value and the engine (input) revolution acceleration command value. Thereby, during the shift operation, while

20   compensating for the achievement of target drive (driving) torque $T*_o$ whose degree of importance is high, a minimum correction of only target engine (input) revolution acceleration u_{io} can move target operating point o to command operating point • within

25   realizable operating region A.

[0095]   When target operating point o corresponding to target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} furthermore moved as a broken line shown in Fig. 13D,

30   post-correction engine (input) revolution acceleration command value indicates a small value as denoted by y_2 derived in the way described with

reference to Fig. 13C. Thus, this command value becomes smaller than preset engine revolution (input) acceleration lower limit set value y_{min}. In this way, if engine (input) revolution acceleration command value u_i which becomes smaller than lower limit set value y_{min} is allowed, engine (input) revolution acceleration command value u_i becomes extremely small so that almost no shift occurs. In worst case, engine (input) revolution acceleration command value u_i indicates a negative value and the situation such that a sense of incompatibility of the shift is developed.

[0096] To avoid such a worst case, as shown in Fig. 13D, in a case where target operating point o is moved, a point of intersection between one of two boundary lines prescribing realizable region A which is nearer to target operating point o (which is called a realizable region boundary line) and a line representing engine revolution (input revolution) acceleration lower limit value y_{min} is set as command operating point •. Drive torque $T*_o$ and engine (input) revolution acceleration u_i at this command operating point • is set as the drive torque command value and the engine (input) revolution acceleration command value. Therefore, the same action and advantage can be achieved, while avoiding engine (input) revolution acceleration command value u_i which does not become less than engine revolution (input revolution) acceleration lower limit set value y_{min}, thus, while the sense of incompatibility for the shift is prevented from occurring, target operating point ? is moved to command operating point ? within the realizable region A with a minimum correction of

target drive (driving) torque $T*_{oo}$ and target engine
(input) revolution acceleration u_{io}. According to
the above-described correction, since the correction
of target drive (driving) torque $T*_{oo}$ and target

5 engine (input) revolution acceleration u_{io} can be
made smoothly and continuously, development of
unnatural vehicular acceleration shock and the
development of the engine revolution speed variation
can be prevented.

10 [0097]   Target value correcting section 103
executes the above-described correction of target
drive (driving) torque $T*_{oo}$ and target engine (input)
revolution acceleration u_{io} (determination of drive
torque command value $T*_{o}$ and engine (input)

15 revolution acceleration u_i) in accordance with the
operational flowchart shown in Fig. 14.
That is to say, at a step S30, target value
correcting section 103 derives realizable region A
represented on the two-dimensional coordinate of

20 drive torque To and engine (input) revolution
acceleration $(d/dt)\omega i$ shown in Figs. 13A through 13D
in the same process as described at step S10 shown in
Fig. 8 and calculates the two boundary lines
prescribing this region according to equations (8)

25 and (9). At a step S31, target value correcting
section 103 derives points of intersections (x_0, y_1)
and (x_0, y_2) between a straight line passing target
operating point (x_0, y_0) corresponding to the
combination of target drive (driving) torque x_0 (=

30 $T*_{oo}$) and target engine (input) revolution
acceleration y_0 (= u_{io}) shown in Figs. 13A through 13D
and expressed in the following equation and which is
parallel to the longitudinal axis, viz., engine

(input) revolution acceleration axis of Figs. 13A
through 13D and the two boundary lines prescribing
realizable region A as shown in Figs. 13A through 13D.
(It is noted that $y_1 < y_2$).

5

$$T_o = T_{oO}^* \quad \ldots (29).$$

[0098]   At a step S32, target value correcting
section 103 determines whether y_0 is present between
y_1 and y_2. If y_0 is present between y_1 and y_2, the
routine goes to a step s33 since the combination of

10   target drive (driving) torque T^*_{oO} and target engine
(input) revolution acceleration u_{io} fall within
realizable region A as shown in Figs. 13A and 13B. If
y_0 is not present between y_1 and y_2 at step S32, the
routine goes to a step S34 since the combination of

15   target drive (driving) torque T^*_{oO} and target engine
(input) revolution acceleration u_{io} is out of
realizable region A as shown in Figs. 13C and 13D.
[0099]   At step S33 which is selected when the
combination of target drive (driving) torque T^*_{oO} and

20   target engine (input) revolution acceleration u_{io}
falls within realizable region A, target operating
point ? which is the combination of target drive
(driving) torque x_0 (=T^*_{oO}) and target engine (input)
revolution acceleration y_0 (= u_{io}) is directly set as

25   the command operating point. Target drive (driving)
torque T^*_{oO} is set directly as post-correction target
drive (driving) torque command value T^*_o and target
drive engine (input) revolution acceleration u_{io} is
directly set as post-correction engine (input)

30   revolution acceleration command value u_i.
[0100]   At step S34 which is selected when the
combination of target drive (or driving) torque T^*_{oO}

and target engine (input) revolution acceleration u_{io}
are out of realizable region A, target value
correcting section 103 derives a point of
intersection (x_0, y_c) between the realizable region
5 boundary line nearer to target operating point $(x_0,$
$y_0)$ and the line expressing $T_o = x_0$ as shown in Figs.
13C and 13D. It is noted that the point of
intersection (x_0, y_c) is a point wherein target drive
(driving) torque $T*_{oo}$ is not changed but target input
10 revolution acceleration u_{io} is moved to a point of y_c
which is within realizable region A and which is
nearest to y_0. At the next step S35, equation (19) is
used to calculate engine (input) revolution
acceleration lower limit set value y_{min}.
15 [0101]   At the next step S36, target value
correcting section 103 determines whether y_c is
located nearer to y_0 side than y_{min} as shown in Fig.
13C. If with reference to y_{min} y_c is located toward y_0
side, a sufficient engine (input) revolution
20 acceleration can be obtained (a sufficient shift
speed can be obtained) so that the routine goes to a
step S37. If, as shown in Fig. 13D, y_c is not located
toward y_c, the sufficient engine (input) revolution
acceleration is not obtained but the above-described
25 problems may occur so that the routine goes to a step
S38.
[0102]   At step S37 selected when the sufficient
engine (input) revolution acceleration can be
obtained (sufficient shift speed can be obtained), as
30 shown in Fig. 13C, point of intersection (x_0, y_c) is
set as command operating point, drive torque $T*_o$ and
engine revolution speed u_i at this command operating
point are set as post-correction drive torque command

value $T*_o$ and post-correction engine (input) revolution acceleration command value u_i. At step S38 selected when no sufficient engine (input) revolution acceleration is obtained (no sufficient shift speed

5   is obtained), as shown in Fig. 13D, the point of intersection at which one of the two realizable region boundary lines which is nearer to target operating point (x_0, y_0) is intersected with the line expressing engine ($d\omega_i/dt$)= y_{min} is set as command

10   operating point. At this command operating point, drive torque $T*_o$ and engine acceleration u_i are set, respectively, as post-correction drive torque command value $T*_o$ and post-correction engine (input) revolution acceleration command value u_i.

15   [0103]   The polarities (signs) of post-correction drive torque command value $T*_o$ and engine (input) revolution acceleration command value u_i are the same as those of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} in

20   the same way as described in the first embodiment. Hence, the same action and advantages as described in the first embodiment can be achieved. While engine (input) revolution acceleration command value u_i is not smaller than engine (input) revolution

25   acceleration (input revolution) lower limit set value y_{min}, hence, no sense of incompatibility for the shift is given, target operating point (x_0, y_0) can be moved to command operating point • within realizable region A with the minimum correction for target drive

30   (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} so that the same action

and advantages as the first embodiment can be achieved.

[0104]   (Third embodiment)

Fig. 15 shows an operational flowchart executed by target value correcting section 103 of the shift control apparatus in a third preferred embodiment according to the present invention, viz., the correction procedure on target drive (driving) torque and target engine (input) revolution acceleration. In the third embodiment, the structure of the hybrid transmission, the shift control system, and shift control function-dependent block diagram are the same as those shown in Figs. 1 through 3. Hence, these explanations will be omitted herein. The correcting method for only target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} will be described hereinbelow on the basis of the control program shown in Fig. 15.

[0105]   In the second embodiment shown in Figs. 13A through 13D and Fig. 14, when target operating point ? which corresponds to the combination of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} is out of realizable region A, target drive (driving) torque $T*_{oo}$ is not corrected so much but target engine (input) revolution acceleration u_{io} is mainly corrected. However, in the third embodiment, on contrary to this, target engine (input) revolution acceleration u_{io} is not so corrected but target drive (driving) torque $T*_{oo}$ is mainly corrected.

[0106]   The target value correcting section 103 in this embodiment calculates two boundary lines prescribing realizable region A expressed on the two-

dimensional coordinates (refer to Figs. 13A through 13D) of the drive torque $T*_o$ and engine (input) revolution acceleration $(d/dt)\omega i$ at a step S40 shown in Fig. 15, in the same processing as step S30 of

5 Figs. 14. At the next step S41, target value correcting section 103 drives points of intersections (x_1, y_0) and (x_2, y_0) between the straight line passing through target operating point (x_0, y_0) correspond to target drive (driving) torque x_0 (=

10 $T*_{oo}$) and engine (input) revolution acceleration y_0 (= u_{io}) and parallel to the drive torque axis (lateral axis of Figs. 13A through 13D) and two realizable region boundary lines (wherein $x_1 < x_2$).

$$\frac{d\omega_i}{dt} = u_{io} \qquad . \quad ...(30).$$

15 [0107] At a step S42, target value correcting section 103 determines whether x_0 falls within an intermediate between x_1 and x_2. If x_0 is determined to be present between x_1 and x_2, the routine goes to a step S43 since the combination of target drive

20 (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} falls within realizable region A. If x_0 is determined not to fall between x_1 and x_2, since the combination of target drive (driving) torque $T*_{oo}$ and target engine (input)

25 revolution acceleration u_{io} is out of realizable region A, the routine goes to a step S44. At step S43 selected when the combination of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} is within realizable

30 region A, target operating point which is the combination of target drive (driving) torque x_0 (=$T*_{oo}$) and target engine (input) revolution

acceleration $y_0 (= u_{io})$ is set directly to command
operating point and target drive (driving) torque
$T*_{oo}$ is set directly as post-correction drive torque
command value $T*_o$, and target drive engine (input)

5   revolution acceleration u_{io} is directly set as post-
correction engine (input) revolution acceleration
command value u_i.

[0108]   At step S44 selected when the combination
of target drive (driving) torque $T*_{oo}$ and target

10   engine (input) revolution acceleration u_{io} is out of
realizable region A, target value correcting section
103 derives the point of intersection (x_c, y_0)
between one of the two boundary lines prescribing the
realizable region which is nearer to target operating

15   pint (x_0, y_0) and the line expressing $(d/dt)\omega i = y_0$.
It is noted that the point of intersection (x_c, y_0)
is a point with target input revolution acceleration
u_{io} unchanged and target drive (driving) torque $T*_{oo}$
is moved to a point x_c within realizable region A

20   which is nearest to x_0. At the next step S45, a
drive torque lower limit set value x_{min} is calculated
using the following equation.

$$X_{min} = Kx \cdot \frac{\sigma_x}{|\sigma_x| + \varepsilon_x} \quad ...(31).$$

It is noted that σ_x denotes a deviation between

25   target engine (input) revolution speed and actual
input revolution speed, ε_x denotes a positive
constant with $\sigma_x = 0$ continuous for x_{min}. Kx denotes a
positive constant obtained, for example, by a
previously experiments and computer simulations.

30   [0109]   At the next step S46, target value
correcting section 103 determines whether x_c is

located toward x_0 side with respect to x_{min}. If x_c is
located toward x_0 side with respect to x_{min}, the
sufficient drive torque can be obtained and the
routine goes to a step S47. If x_c is not located

5   toward x_0 side, a sufficient drive torque cannot be
obtained and the routine goes to a step S48. At step
S47 selected when the sufficient drive torque is
obtained, the point of intersection (x_c, y_0) is the
command operating point and drive torque $T*_0$ and

10   engine (input) revolution acceleration u_{i0} at this
command operating point is set to post-correction
drive torque command value T*o and post-correction
engine (input) revolution acceleration command value
u_i. At step S48 selected when no sufficient drive

15   torque is obtained, a point of intersection between
one of the two realizable region boundary lines which
is nearer to target operating point (x_0. y_0) and the
line expressing drive torque To = x_{min}. is the command
operating point. The drive torque T*o and engine

20   (input) revolution acceleration command value u_i,
respectively, at this command operating point, are
set to post-correction drive torque command value $T*_0$
and post-correction engine (input) revolution
acceleration command value u_i.

25   [0110]   Hence, post-correction drive torque command
value $T*_0$ and engine (input) revolution acceleration
command value u_i have respectively the same
polarities of target drive (driving) torque $T*_0 o$ and
target engine acceleration u_{i0} as described in the

30   second embodiment. The same action and advantages can
be achieved. While drive torque command value $T*_0$ is
smaller than predetermined drive torque limit value

set value x_{min}, target operating point (x_o, y_o) can be
moved to the command operating point within
realizable region A with minimum correction of target
drive (driving) torque $T*_{oo}$ and target engine (input)
5   revolution u_{io}.
[0111]   (Fourth Embodiment)
Fig. 16 shows another type of hybrid transmission in
which motor/generators MG1 and MG2 are individually
and independently installed as different from
10 motor/generators MG1 and MG2 which is constituted by
compound current two-layer motor 3. That is to say,
circular ring shaped stators 3s1 and 3s2 are
coaxially arranged and fixedly mounted within
transmission casing 1, and rotors 3r1 and 3r2 are
15 revolutionally supported by means of stators 3s1 and
3s2. Circular ring shaped stator 3S1 and rotor 3r1
constitute first motor/generator MG1 near to engine
ENG and circular ring shaped stator 3s2 and rotor 3r2
constitute second motor/generator MG2 which is
20 located far away from engine ENG.
[0112]   Motor/generators MG1 and MG2 function as
respectively motors in accordance with a supply
current when a current is supplied to ring shaped
stators 3s1 and 3s2, individually, in an individual
25 direction. When no current is supplied, each
generator is acted which develops the electrical
power in accordance with the revolution by means of
an external force.
[0113]   When motor/generators MG1 and MG2 are
30 coupled to Ravigneaux type planetary gear set 2,
rotor 3r2 of first motor/generator MG1 is coupled to
sun gear S1 of Ravigneaux type planetary gear set via

axle 11 and a rotor 3r2 of second motor/generator MG2 is coupled to sun gear S2 via axle 12.

[0114]   In a case where the hybrid transmission is used having the above-described motor/generators MG1

5   and MG2 as shown in Fig. 16. a control current of motor/generators MG1 and MG2 is required to be supplied to ring shaped stators 3s1 and 3s2 individually. Hence, the control system is as shown in Fig. 17 in place of those shown in Fig. 12. That

10   is to say, in the case of Fig. 2, a single inverter common to both motor/generators MG1 and MG2 is only installed.   However, in the case of Fig. 17, an inverter 24a for ring shaped stator 3s1 of the first motor/generator MG1 and an inverter 24b for ring

15   shaped stator 3s2 is individually installed for ring shaped stator 3s2 of second motor/generator MG2.

[0115]   In this embodiment, hybrid controller 21 is shown in the form of functional block diagram as shown in Fig. 3. In this embodiment, however, the

20   processes in target value correcting section 103 and motor/generator command value determining section 105 are different from that shown in Fig. 3.

[0116]   The process at target value correcting section 103 is, in the same way as described in first,

25   second, and third embodiments, such that, in a case where the target operating point corresponding to the combination of target drive (driving) torque and target engine (input) revolution acceleration is out of realizable region on the two-dimensional

30   coordinate on the drive torque and engine (input) revolution acceleration, these target drive (driving) torque and/or target engine (input) revolution acceleration are corrected to the drive torque

command value and engine (input) revolution acceleration command value on the command operating point within the realizable region. In this preferred embodiment, the realizable region on the

5 two-dimensional coordinates on the drive torque and engine (input) revolution acceleration is different from realizable region denoted by A shown in Figs. 6, 7A through 7C, and 13A through 13D, as will be described below.

10 [0117] From the relationship among drive torque To, engine (input) revolution acceleration $(d/dt)\omega i$, engine revolution speed ωi, output revolution speed ωo, running resistance torque T_R, engine torque T_E, and battery charge-and-discharge quantity P_B,, the

15 two-dimensional coordinate with the lateral axis taken as drive torque To and the longitudinal axis taken as engine (input) revolution acceleration $(d/dt)\omega i$, a realizable region which falls within the battery rated power is represented as A shown in Fig.

20 6. In this embodiment, a region BC of drive torque and engine (input) revolution acceleration by means of a torque mechanically generable through motor/generators MG1 and MG2 is derived as shown in Fig. 18 and a region D shown in Fig. 19 which is an

25 overlapped region between region BC and region A is called realizable region.

[0118] Before explanation of the derivation of region BC, engine (input) revolution acceleration of the hybrid transmission is expressed as in equation

30 (11) and the drive torque is expressed as in equation (12). $I_c b_{24}$ x equation (11) - b_{14} x equation (12).

$$I_c b_{24} \frac{d\omega_i}{dt} - b_{14} T_0 = (I_c b_{24} b_{11} - I_c b_{14} b_{21} + 1) T_R + I_c (b_{24} b_{12} - b_{14} b_{22}) T_E + I_c (b_{24} b_{13} - b_{14} b_{23}) T_1 \quad \ldots \quad (32).$$

[0119]   In addition, the following equation can be derived from $I_c b_{23}$ x equation (11) - b_{13} x equation (12).

$$I_c b_{23} \frac{d\omega_i}{dt} - b_{13} T_o = (I_c b_{23} b_{11} - I_c b_{13} b_{21} + 1) T_R + I_c (b_{23} b_{12} - b_{13} b_{22}) T_E + I_C (b_{23} b_{14} - b_{13} b_{24}) T_2$$
$$\ldots \quad (33).$$

[0120]   Using equation (32), from the torque range generable mechanically by motor/generator MG1, the drive torque mechanically generable torque of motor/generator and a region B of engine (input) revolution acceleration can be obtained from Fig. 18. In addition, using equation (33), from a torque range that second motor/generator MG2 mechanically generable, a region C of the drive torque mechanically generable by second motor/generator and engine (input) revolution acceleration can be obtained as shown in Fig. 18. In a case where the independent two motor/generators MG1 and MG2 are used, a region B is uniquely determined without exception from the revolution speed of the present motor/generator MG1 and region C is uniquely determined without exception from the revolution speed of the present motor/generator MG2. It is noted that a region on which region B and region C are overlapped is assumed to be BC.

[0121]   Then, as shown in Fig. 19, a realizable region D between drive torque and engine revolution speed is assumed on which region A and region BC are overlapped is assumed. In each of the above-described first through third embodiments, since

motor/generators are constituted by the composite
current two-layer motor 3, region BC is not obtained.
A dependent relationship is present as expressed in
equation (16) between revolution speed of
5   motor/generator MG2, maximum torque T_{1max} of
motor/generator MG1, and maximum torque T_{2max} of
second motor/generator MG2. This dependent
relationship causes the dependent relationship
between regions B and C, as shown in Fig. 20, under
10   the revolution speed of present motor/generator MG1
and revolution speed of present motor/generator MG2,
as shown in Figs. 20A, 20B, and 20C.
Region B is narrower as T_{2max} becomes smaller (T_{1max}
becomes larger) and wider as T_{2max} becomes larger,
15   (T_{1max} is smaller). On the other hand, region C
becomes wider as T_{2max} becomes smaller (T_{1max} becomes
larger), as shown in Figs. 20A, 20B, and 20C. As
described above, since region B and region C are
variable, region BC on which both are overlapped is
20   variable.   It is difficult to include this region BC
in realizable region D, as shown in Fig. 19.
[0122]   Hereinafter, the process by means of target
value correcting section 103 shown in Fig. 3 is
executed in accordance with the flowchart shown in
25   Fig. 21 in place of the program shown in Fig. 8.
At a step S250, target value correcting section 103
determines whether target operating point which is
the combination of target drive (driving) torque x_0
($= T_{*00}$) and target engine (input) revolution
30   acceleration y_0 ($= u_{10}$) falls within realizable region
D described above so as to determine whether target
engine torque $T*_{00}$ and target engine (input)
revolution acceleration u_{10} are feasible.

[0123]   The determination of feasibility is based
on the determination of whether target drive
(driving) torque $T*_{oo}$ and target engine (input)
revolution acceleration u_{io} are feasible when the
following three conditions are satisfied.
(Condition 1)
The battery-and-discharge quantity when target drive
(driving) torque $T*_{oo}$ and target engine acceleration
u_{io} are substituted into equation (7) is equal to or
below the battery rated power.
(Condition 2)
T_1 when target drive (driving) torque $T*_{oo}$ and target
revolution acceleration u_{io} are substituted into
equation (32) is a torque mechanically generable at
the present revolution speed of the first
motor/generator MG1.
(Condition 3)
T2 when target drive (driving) torque $T*_{oo}$ and target
engine (input) revolution acceleration u_{io} are
substituted into equation (33) is a mechanically
generable torque at the present revolution speed of
the motor/generator MG2.
[0124]   In a case where target drive (driving)
torque $T*_{oo}$ and target engine (input) revolution
acceleration u_{io} are determined to be feasible
(realizable) at step S50,
at a step S51, target value correcting section 103
sets the target operating point which is a
combination of target drive (driving) torque x_0 (=
$T*_{oo}$) and target engine (input) revolution
acceleration y_0 (= u_{io}) directly as the command
operating point, target drive (driving) torque $T*_{oo}$

is set directly as post-correction drive torque command value $T*_0$, target drive engine (input) revolution acceleration u_{1o} is directly set as post-correction engine acceleration command value u_1.

[0125]   In a case where target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{1o} are determined not to be realizable at step S50, at a step S52, from among points of intersections at which a line segment connecting an origin and the target operating point (x_0, y_0) is intersected with boundary lines of origin A, origin B, and origin C, one point of intersection which is within the realizable region D and which is nearest to target operating point is the command operating point, the drive torque $T*_0$ and engine (input) revolution acceleration u_1 are respectively set as post-correction drive torque command value $T*_0$ and as post-correction engine (input) revolution acceleration value u_1.

[0126]   In this embodiment, the process carried out by motor/generator torque command value determining section 105 shown in Fig. 3 is such that, in the same manner as described in each embodiment, when target motor/generator torques $T*_{10}$ and $T*_{20}$ from motor/generator torque distributing section 104 are in excess of mechanically output enable torque range or in excess of the battery rated power (is out of operable region), these are output enable range and a value within the battery rated power, these are corrected to values thereof within output enable torque range and battery rated power to form motor/generator torque command values $T*_1$ and $T*_2$. Thereby, motor/generator torque command value

determining section 105 functions as the protection
function against the deterioration of
motor/generators MG1 and MG2, earlier deterioration
of battery, performs a protection function described
5 above, and performs a fail safe function.
[0127]   Hence, also in this embodiment,
motor/generator torque command value determining
section 105 in accordance with a determination result
of step S20 shown in Fig. 9, in details, in
10 accordance with the determination of whether
motor/generator torques $T*_{10}$ and $T*_{20}$ are within the
operable region or are out of the operable region
performs the same process as step S21 and step S22.
The determination method at step S20 at which the
15 contents of processes of any step should be executed
is different. Hereinafter, the details thereof will
herein be described. When this determination is
carried out, in other words, when target
motor/generator torques $T*_{10}$ and $T*_{20}$ are determined
20 to fall within operable region. When the
determination whether it is out of the region, this
determination is made on the basis of regional
diagram shown in Fig. 22.
[0128]   It is noted that Fig. 22 shows the
25 regional diagram used in this embodiment. In Fig. 22,
the lateral axis denotes a torque T_1 of first
motor/generator torque MG1 and the longitudinal axis
denotes a torque T_2 of the second motor/generator MG2
so that the two-dimensional coordinates are formed.
30 On the two-dimensional coordinates, an operable
region FX which can achieve toques of first and
second motor/generators MG1 and MG2 is shown.   The
region FA and region FC are the same as those

described with reference to Fig. 10. and the duplicate explanation will herein be omitted.

[0129] Next, to derive a mechanical operable region of independent two motor/generators MG1 and MG2, in a case of the hybrid transmission having independent two motor/generators MG1 and MG2, an operable range of the torque of first motor/generator MG1 is uniquely determined according to the revolution speed of motor/generator MG1 and the operable range of the torque of the second motor/generator MG2 is uniquely determined according to the revolution speed of motor/generator MG2. Hence, using the relationship between revolution speeds ω_1 and ω_2 of first and second motor/generators MG_1 and MG_2 and maximum torques T_{1max} and T_{2max} of first and second motor/generators MG1 and MG2, maximum torque T_{1max} of first motor/generator MG1 is obtained from the present revolution speed ω_1 of first motor/generator MG1 and maximum torque T_{2max} of second motor/generator MG2 is obtained from the present revolution speed ω_2 of second motor/generator MG2.

[0130] From these motor/generator maximum torques T_{1max} and T_{2max}, a mechanical operable region FB of motor/generators MG1 and MG2 is obtained as shown in Fig. 22. In the case of the hybrid transmission having independent two motor/generators MG1 and MG2, operable region FB is a rectangular shape. An overlapped area between region FB and region FC are operable region FX of motor/generators MG1 and MG2.

[0131] On the basis of Fig. 22, the target value correcting section 103 determines whether target motor/generator torques T_{*10} and T_{*20} are within operable region FX or out of operable region FX. When

the following four conditions are satisfied, it can

be determined that motor/generator torques $T*_{10}$ and

$T*_{20}$ are within operable region FX.

(Condition I)

5 In Fig. 23A, battery charge-and-discharge quantity

Obtained by substituting target motor/generator

torques $T*_{10}$ and $T*_{20}$ into equation (15) is equal to

or lower than battery rated power.

(Condition II)

10 In Fig. 22A, target motor/generator torque $T*_{10}$ is

present within a range of maximum torque T_{1max} of

motor/generator MG1 obtained from the present

revolution speed ω_1 of motor/generator MG1.

(Condition III)

15 In Fig. 23B, target motor/generator torque $T*_{20}$ is

present within a range of maximum torque T_{1max} of

motor/generators MG1 obtained from the present

revolution speed ω_2 of motor/generator MG2 .

(Condition IV)

20 If $b_{11}T_R + b_{12}T_E + b_{13}T*_{10} + b_{14}T*_{20} \geq 0$, target

motor/generator torques $T*_{10}$, $T*_{20}$ satisfy the

relationship of equation (17) described above and if

$b_{11}T_R + b_{12}T_E + b_{13}T*_{10} + b_{14}T*_{20} \leq 0$. both of target

motor/generator torques $T*_{10}$, $T*_{20}$ satisfy the

25 relationship of equation (18).

[0132]   In this embodiment, when the above-

described four conditions are satisfied at step S20

in Fig. 9, target motor/generator torques $T*_{10}$ and

$T*_{20}$ are within operable region FX and the step S21

30 of the same drawing is executed. When, at step S20 of

Fig. 9, the above-described four conditions are not

satisfied, the step S22 is executed since

motor/generator torques $T*_{10}$, $T*_{20}$ are out of operable region FX. Therefore, the same action and advantages as described in each of the first through third embodiment can be achieved.

5 [0116]   (Fifth embodiment)

Fig. 24 shows a correction procedure of target drive (driving) torque and target engine (input) revolution acceleration in place of Fig. 21 and to be executed in a fifth preferred embodiment of the shift control

10 apparatus according to the present invention.

[0117]   In this embodiment, the hybrid transmission is the same as Fig. 16 and the shift control system is the same as Fig. 17. Furthermore, hybrid controller 21 in Fig. 16 is the same as Fig. 3 when

15 the functional block diagram is shown. Target value correcting section 103 executes the flowchart of Fig. 24 in place of Fig. 21.

[0118]   Herein, a processing of the flowchart shown in Fig. 24 executed by target value correcting

20 section 103 will be described below.

[0119]   At a step S60, in the same way as described at step S50 shown in Fig. 21, depending upon whether the target operating point which is the combination of target drive (driving) torque x_0 (= $T*_{00}$) and

25 target engine (input) revolution acceleration y_0 (= u_{10}) falls within realizable region D shown in Fig. 19, a kind of check by means of target value correcting section 103 is made as to whether target drive (driving) torque $T*_{00}$ and target engine (input)

30 revolution acceleration u_{10} is feasible.

[0120]   If, at step S60, the determination is made that target drive (driving) torque $T*_{00}$ and target engine (input) revolution acceleration u_{10} are

determined to be feasible, the routine goes to a step

S61. At step S61, the target operating point is set

directly as the command operating point which is the

combination of target drive (driving) torque x_0 (=

5    $T*_{oo}$) and target engine (input) revolution

acceleration y_0 (= u_{io}), target drive (driving) torque

$T*_{oo}$ is directly set as post-correction drive torque

command value $T*_o$, and target engine (input)

revolution acceleration u_{io} is directly set as post-

10   correction engine (input) revolution acceleration

command value u_1. In a case where, at step S60, if

determination is made that target drive (driving)

torque $T*_{oo}$ and target engine (input) revolution

acceleration u_{io} are not feasible, the routine goes

15   to a step S62. In the same way as described with

reference to step S34 in Fig. 14, target value

correcting section 103 derives points of

intersections (x_0, y_c) between boundary lines of

regions A, B, and C (refer to Figs. 18 and 19) which

20   are nearest to target operating point (x_0, y_0) within

realizable region D and a line expressing $T_o = x_0$.

It is noted that point of intersection (x_0, y_c) is a

point at which target drive (driving) torque $T*_{oo}$ is

left unchanged and target input revolution

25   acceleration u_{io} is moved to a point y_c within

realizable region D which is nearest to y_0.

[0138]   At the next step S63, target value

correcting section 103 calculates engine (input)

revolution acceleration lower limit set value y_{min} in

30   the same way as described with reference to step S35

of Fig. 14. At the next step S64, in the same way as

step S36 in Fig. 14, target value correcting section

103 determines whether y_0 falls within y_0 side with

respect to y_{min}. If y_c is located at y_0 side with respect to y_{min}, the sufficient engine (input) revolution acceleration (the sufficient shift speed) can be obtained. Thus, the routine goes to a step S66. If y_c is not located toward y_0 side with respect to y_{min}, the routine goes to a step S66.

[0139]   At a step S65 selected when the sufficient engine (input) revolution acceleration is obtained (the sufficient shift speed is obtained), in the same way as step S37 in Fig. 14, the point of intersection (x_0, y_c) is set as the command operating point, the drive torque $T*o$ and engine (input) revolution acceleration u_i at this command operating point are set as post-selection drive torque command value $T*o$ and post-correction engine input revolution acceleration command value u_i. At the step S66 selected when the engine (input) revolution acceleration cannot be obtained sufficiently (a sufficient shift speed is not obtained), in the same way as described with reference to step S38 in Fig. 14, a point of intersection which is nearest to the target operating point (x_0, y_0) within realizable region D from among the point of intersections at which the boundary lines of regions A, B, and C (refer to Figs. 18 and 19) are intersected with the line representing the engine (input) revolution acceleration $(d/dt)\omega i = y_{min}$ is set as the command operating point, drive torque $T*_0$ and engine (input) revolution acceleration u_i at this command operating point are set as post-correction drive torque command value T_{o*} and post-correction engine (input) revolution acceleration command value u_i.

[0140]   Hence, the post-correction drive torque command value $To*$ and engine (input) revolution acceleration command value u_i have the same polarities as those of the target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io}. The same action and advantages as described in each of the previously described embodiments can be achieved. While the sense of incompatibility with the shift is prevented from occurring (engine revolution (input revolution) acceleration command value u_i does not become a value lower than (predetermined) engine revolution (input revolution) acceleration lower limit value y_{min}, target operating point (x_0, y_0) can be moved to the command operating point within realizable region D with minimum correction of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io}. Consequently, the same action and advantages as described in each of the first through fourth embodiments can be achieved.

[0141]   (Sixth Embodiment)

Fig. 26 shows a correction processing of target drive (driving) torque and target engine (input) revolution acceleration in place of Fig. 21 to be executed by the shift control apparatus of the hybrid transmission in a sixth preferred embodiment according to the present invention. The hybrid transmission in the sixth embodiment is the same as that shown in Fig. 16 and the shift control system is the same as that shown in Fig. 17. Furthermore, hybrid controller 21 in Fig. 16 is the same as depicted in Fig. 3. However, target value correcting section 103 in this embodiment is different from that

shown in Fig. 3 in that target value correcting section 103 in this embodiment executed the flowchart shown in Fig. 25 in place of that shown in Fig. 21. Hereinafter, the processing of flowchart that target value correcting section 103 executes will be described below with reference to the flowchart of Fig. 25.

[0142] At a step S70, target value correcting section 103 determines whether the target operating point which is the combination of target drive (driving) torque $x_0 (= T*_{oo})$ and target engine (input) revolution acceleration $y_0 (= u_{io})$ falls within realizable region D shown in Fig. 19 so as to determine whether target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} are feasible.

[0143] In a case where, at step S70, target value correcting section 103 determines that target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io} are feasible, at a step S71, in the same way as contents of step S51 shown in Fig. 21, the target operating point which is the combination of target drive (driving) torque x_0 (= $T*_{oo}$) and target revolution acceleration y_0 (= u_{io}) is set directly as the command operating point, target drive (driving) torque $T*_{oo}$ is directly set as post-correction drive torque command value $T*_o$, and target drive engine (input) revolution acceleration u_{io} is directly set as post-correction engine (input) revolution acceleration command value u_i.

[0145] In a case where, at step S70, target value correcting section 103 determines that target drive

(driving) torque $T*_{oO}$ and target engine (input)
revolution acceleration u_{io} are not feasible, the
routine goes to a step S72. AT step S72, in the same
way as described in step S44 shown in Fig. 15, target
5   value correcting section 103 derives a point of
intersection (x_c, y_0) between one of the boundary
lines of regions A, B, and C (refer to Figs. 18 and
19) which is nearest to target operating point (x_0,
y_0) and which is within realizable region D and a
10   line expressing $(d/dt)\omega i = y_0$.
[0146]   Next, at a step S74, target value
correcting section 103 determines whether x_c is
located toward x_0 side with respect to x_{min}, in the
same way as described at step S46 shown in Fig. 15.
15   If x_c is located toward x_0 side with respect to x_{min},
the drive torque can sufficiently be obtained and the
routine goes to a step S75. If x_c is not located
toward x_0 side with respect thereto, the sufficient
drive torque cannot be obtained so that the routine
20   goes to a step S76.
[0147]   At step S75 selected when the sufficient
drive torque is obtained, in the same manner as the
step S41 of Fig. 15, point of intersection (x_c, y_0)
is set as the command operating point, drive torque
25   $T*_o$ and engine (input) revolution acceleration u_i is
set as post-correction drive torque command value $T*_o$
and post-correction engine (input) revolution
acceleration command value u_i. On the other hand, at
step S76 selected when the sufficient drive torque
30   cannot be obtained, in the same way as described at
step S38 shown in Fig. 13, point of intersection
which is nearest to target operating point (x_0, y_0)
within realizable region D from among the points of

intersections between the boundary lines of regions A, B, and C (refer to Figs. 18 and 19) and a line expressing drive torque To = x_{min} is set as the command operating point. Drive torque $T*_o$ and engine

5 (input) revolution acceleration u_i at this command operating point are set, respectively, as post-correction drive torque command value $T*_o$ and post-correction engine (input) revolution acceleration command value u_i.

10 [0148] Hence, the polarities (signs) of post-correction drive torque command value $T*_o$ and post-correction engine (input) revolution acceleration command value u_i are the same as those of target drive (driving) torque $T*_{oo}$ and target engine (input)

15 revolution acceleration u_{io}. Thus, the same action and advantages as those of each of the first through fifth embodiments can be achieved. While preventing drive torque command value $T*_o$ from becoming lower than drive torque lower limit value x_{min}, target

20 operating point (x_o, y_o) can be moved to the command operating point within realizable region D with minimum correction of target drive (driving) torque $T*_{oo}$ and target engine (input) revolution acceleration u_{io}.

25 [0149] Various changes and modifications may be made without departing from the scope and sprit of the present invention which is defined in the appended claims.

[0150] The entire contents of a Japanese Patent

30 Application No. 2003-100773 (filed in Japan on April 3, 2003) are herein incorporated by reference. The scope of the invention is defined with reference to the following claims.